Regeneration, Reconstruction & Restoration

Original Article

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Evaluation of the Relationship of the Maxillary Sinus Floor with Maxillary Molars Using Cone-Beam Computed Tomography

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Article Info

Received: 1 May, 2025

Accepted: 2 August, 2025

Published: 18 August,2025

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Abstract

Background and objectives: Considering the proximity of the roots of maxillary molars to the maxillary sinus floor (MSF) and their sensitivity to odontogenic and non-odontogenic lesions, this study aimed to show the relationship between the roots of maxillary molars and the MSF using cone beam computed tomography (CBCT).

Materials and methods: This cross-sectional study included the CBCT images of 148 fully erupted maxillary molar teeth. The evaluation included the vertical relationship between the maxillary molar and the MSF, the angle of divergence between the apex of the molar roots and the thickness of the cortex of the MSF, and the distance between the apex of the molar roots and the MSF. All parameters were analyzed by sex and age. Data were analyzed using SPSS version 22. A P-value less than 0.05 was considered statistically significant.

Results: The most frequent type of vertical relationship included the lack of root contact with the sinus border and the presence of the MSF cross-section above the root apex (type I), which was significantly more common among women than men. The highest angular deviation among the three molar roots was observed in the first molar, and the angle of divergence between the buccal (B) and palatal (P) roots was greater than the angle between the B roots.

Conclusion: Based on the results of this study, the roots of the maxillary molars are far from the MSF in most cases, and the greatest divergence of the roots is related to the first molar, and this tooth should be extracted cautiously.

Keywords: Cone-beam computed tomography, Maxilla, Molar, Maxillary sinus floor.

Please cite this paper as:
Gholampour A, Mollaei M, Ghobadi F, Salehi M, Hosseinnataj A, Gholami Y. Evaluation of the Relationship of the Maxillary Sinus Floor with Maxillary Molars Using Cone-Beam Computed Tomography. Journal of "Regeneration, Reconstruction & Restoration" (Triple R). 2025; Volume 10: e6. Doi: 10.22037/rrr.v10.47452

1. Introduction

The maxillary sinus is the first paranasal sinus to develop during the second month of fetal life (1). At the time of birth, each sinus presents as a narrow, thin slit, with its anterior-posterior dimensions not exceeding 8 mm in length. As development progresses, the maxillary sinus undergoes progressive pneumatization, expanding into an air cavity within the bone, extending laterally from beneath the orbit to the zygomatic process and from below to the alveolar process. This pneumatization in the alveolar region causes an elevation of the maxillary sinus floor (MSF), which should be assessed concerning the roots of premolar and molar teeth (2).

During the development of the third molar, a signaling mechanism is activated to inhibit further growth of the sinus. The expansion of the lower sinus is associated with dental eruption; when a tooth erupts, the resultant vacated space

becomes pneumatized, leading to an increase in the sinus lumen (3). The walls of the sinus are lined with the Schneiderian membrane, which shows changes in response to various sinus pathologies (4). Consequently, due to the presence of only a single layer of mucosa or cortical bone at the MSF, there exists a heightened risk for the development of oral-sinus fistulas or infections within the sinus cavity (5).

The proximity of the roots of the maxillary molars to the MSF necessitates careful consideration prior to undertaking dental procedures involving these roots. This proximity increases the risk of foreign body entry into the sinus and the potential for infection spread. Surgical interventions, including root canal treatments, tooth extractions, and implant placements, may lead to complications such as sinusitis, oral-sinus fistulas, and root displacement into the sinus cavity (6). The vertical relationship between the roots of the maxillary molars and the MSF can vary based on factors such as age, size, and degree of sinus pneumatization (5). In surgical contexts, particularly endodontic procedures, a thorough evaluation of this relationship prior to surgery can prevent potential complications in the sinus (4).

Two-dimensional radiographic modalities, such as periapical and panoramic imaging, have limitations—including magnification, distortion, and superimposition—that may hinder accurate interpretation of the relationship between the roots of the maxillary molars and the MSF. In contrast, Cone Beam Computed Tomography (CBCT) offers three-dimensional imaging without superimposition, thereby addressing the limitations associated with two-dimensional imaging techniques (7-10).

Given the intimate relationship between the maxillary sinus and the maxillary molars, sinus pathologies may present symptoms similar to those of odontogenic diseases; conversely, odontogenic conditions may also impact the maxillary sinus. Noting discrepancies in outcomes across similar studies, the current investigation aimed to investigate the relationship between the roots of maxillary molars and the MSF utilizing CBCT within the Iranian population.

2. Materials and methods

The current cross-sectional investigation included the CBCT radiographs of patients referred to a private oral and maxillofacial radiology center in Babol, Mazandaran, Iran, between 2019-2022 using the simple random sampling method.

In Zhang's study, the shortest distance between the MSF and molar apex was reported to be 3.33 ± 1.57 mm (5). Considering their findings, the first type error of 5%, the test power of 90%, the measurement error (d) of 0.8 mm, and using the following formula, the sample size was calculated to be 148 images:

$$n = \frac{\left(z_{1-\frac{\alpha}{2}} + z_{1-\beta}\right)^2 * \sigma^2}{(d)^2}$$

The inclusion criteria included CBCT archives of patients between 18 to 85 years old who had previously prepared CBCT for diagnosis purposes and were not exposed to radiation due to this study. The scans exhibited at least the lower ⅓ of the maxillary sinus along with full eruption of the maxillary first and second molars and second premolars. The exclusion criteria were as follows:

1) Presence of impacted third molars
2) extensive caries in the first and second molars requiring endodontic therapy
3) history of root canal treatment or any type of surgery in the maxillofacial region
4) history of trauma or tumor in the maxillofacial region
5) presence of periapical pathology, periodontal disease, or root resorption
6) history or existing orthodontic treatment
7) fused roots or fewer or more than 3 roots
8) poor quality CBCT due to the presence of metal or motion artifacts (6)

All images were prepared by NewTom Giano (Verona, Italy). Exposure conditions for all images included FOV 11x8 cm, kvp 90, mA 10, voxel size 100 µm. Images were reconstructed by NNT software (Verona, Italy).

The vertical relationship between the roots of the maxillary molars and the MSF was determined according to the Kwak classification (11):

I) The inferior wall of the maxillary sinus, situated above the plane that connects the apices of the buccal (B) and palatal (P) roots.

II) The inferior wall of the subsurface sinus that connects the apices of the B and P roots, without any apical protrusion into the sinus wall.

III) The apical protrusion of the B root towards the inferior wall of the sinus.

IV) The apical protrusion of the P root towards the inferior wall of the sinus.

V) The protrusion of both the B and P root apices towards the inferior wall of the sinus (Figure 1).

The divergence angle of the B roots was measured using panoramic images and the divergence angle between the B and P roots in the cross-sectional view. The longitudinal axis of both roots was drawn in the upper ⅓ of the root, and their intersection was considered as the divergence angle (Figure 2). In order to measure the distance from the apex of the roots to the MSF, a horizontal line tangent to the deepest point of the sinus was drawn, and then a line was drawn vertically from the apex to the horizontal line. Positive size meant that the root was far from the sinus, while the negative size implied that the protrusion of the root into the sinus (Figure 3).

Moreover, the thickness of the MSF cortex in the furcation region was also measured (Figure 4).

Descriptive indices such as mean, standard deviation, frequency, and percentage were used for statistical analysis. In order to compare the performance of the techniques, chi-square, Fisher's exact, independent t, analysis of variance, and correlation coefficient, or their non-parametric equivalent, were used. The hypothesis of normality was investigated with the Kolmogorov-Smirnov test. SPSS software version 22 was

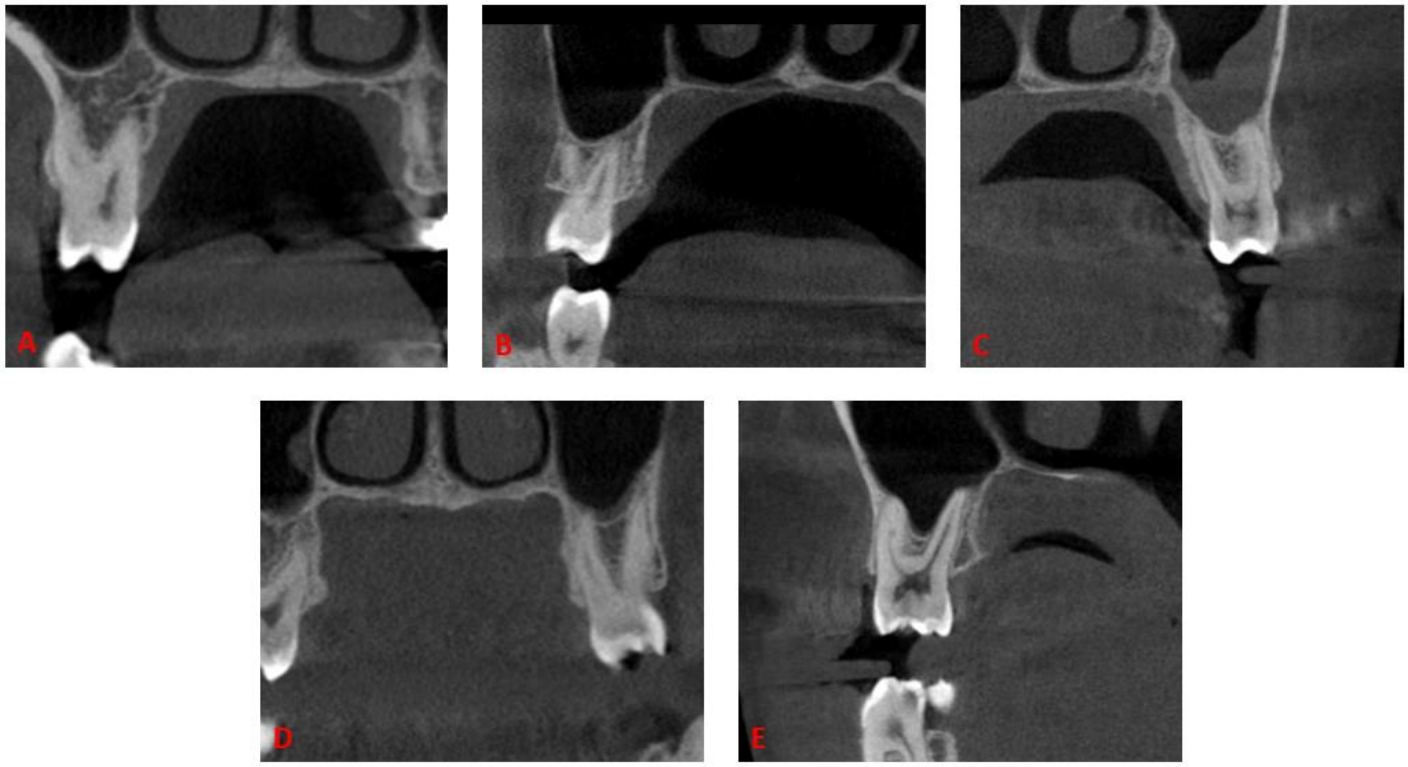

Figure 1. The vertical relationship between the roots of the maxillary molars and the MSF. A) type I, B) type II, C) type III, D) type IV, E) type V.

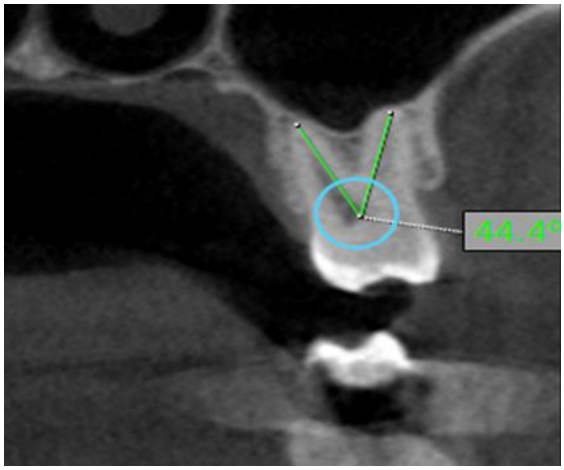

Figure 2. Measurement of the angle of divergence between the roots.

used for statistical calculations, and the significance level was considered 0.05.

3. Results

In this study, the CBCT images of 148 maxillary first and second molars were examined in 55 patients with an average age of 36.98 ± 9.02 years (ranging from 18 to 85). 47.3% of the molars were located on the right side of the maxilla, and 52.7% were on the left side. Descriptive information based on the participants and image is shown in Table 1.

In Table 2, the frequency of vertical relationships was compared according to the type of molar, and it was observed that type I was the most frequent. No significant difference was observed between the frequency of the type of vertical relationship and the side of the teeth (right or left) ($P > 0.05$). Moreover, there was a significant relationship between vertical relationship and sex ($P = 0.001$), and the most common vertical relationship in men and women was type I. Furthermore, no significant relationship was observed between vertical relationship and age ($P > 0.05$).

The tooth type variable did not have a normal distribution; therefore, the Mann-Whitney test was used to compare the root apex–MSF distance to tooth type. According to Table 3, there was no significant difference between the MSF and the root apex based on sex ($P > 0.05$). The most adjacent root to the MSF was the mesiobuccal (MB) and P root in men and women, respectively.

The independent t-test was used to compare the cortical bone thickness and inter-root angles (DB-MB, P-MB, and P-DB) according to molar type, side, and sex. The findings of comparing the average angles and thickness of the cortex in the furcation area showed that the average distobuccal (DB) and palatal (P) angle, mesiobuccal (MB) and P angle, and MB and DB angle in the first molar were significantly higher than the second molar ($P < 0.001$). In the first and second molars, the greatest divergence angle was related to the angle between the DB and P roots. No significant relationship was observed

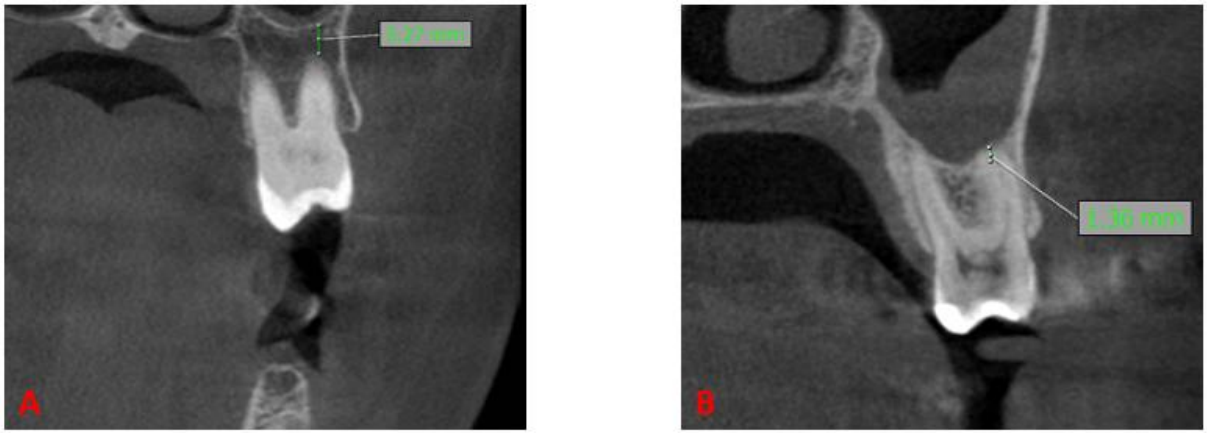

Figure 3. Association of the roots and sinus. A) the root far from the sinus, B) the root protruded into the sinus.

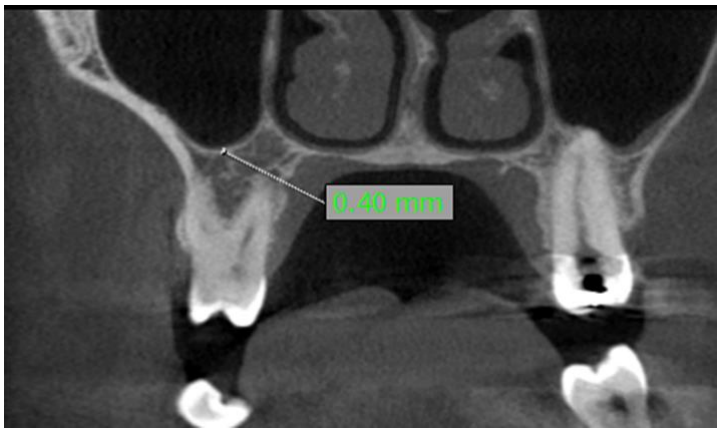

Figure 4. Measurement of the MSF thickness.

Table 1. Descriptive features of the participants and CBCT image.

Variables		Patient		CBCT Image	
		Number	%	Microleakage	%
Sex	Woman	40	72.7	113	76.4
	Man	15	27.3	35	23.6
	Total	55	100	148	100
Side of the molar	Right	-	-	70	47.3
	Left	-	-	78	52.7
				148	100

between cortex thickness and molar type. In the right and left molars, the angle between the DB and P roots was the highest, and no significant relationship was observed between the thickness of the cortex and the angles of the roots of the molars with the maxillary side (right and left).

Additionally, the mean MB, DB angle was significantly higher in men than in women ($P < 0.001$), but no significant difference was observed in terms of the mean DB, P angle, MB, P angle, and cortex thickness according to sex ($P > 0.05$). The highest divergence angle in men and women was related to the angle between the DB and P roots. No significant relationship was observed between cortex thickness and sex.

Table 2. Distribution of Vertical relationships according to tooth type, side, and sex.

Vertical relationship	Type of teeth		Side of teeth		Sex	
	1st molar	2nd molar	Right	Left	Woman	Man
I	38 (54.3)	46 (59.0)	44 (59.4)	40 (54.0)	67 (59.4)	17 (48.6)
II	12 (17.1)	11 (14.1)	12 (16.2)	11 (14.8)	11 (9.7)	12 (34.3)
III	3 (4.3)	11 (14.1)	7 (9.5)	7 (9.5)	12 (10.6)	2 (5.7)
IV	8 (11.4)	2 (2.6)	3 (4.1)	7 (9.5)	6 (5.3)	4 (11.4)
V	9 (12.9)	8 (10.2)	8 (10.8)	9 (12.2)	17 (15.0)	0
Total	70 (47.29)	78 (52.71)	74 (50)	74 (50)	113 (76.4)	35 (23.6)
P value*	0.071		0.755		0.001	

* chi-square

Table 3. Comparing the root apex–MSF distance to tooth type.

Distance	Type of teeth		P-value*	Sex		P-value*
	1st molar	2nd molar		Woman	Man	
DB root-MSF	1.89 ± 2.57	1.77 ± 2.82	0.759	1.86 ± 2.89	1.65 ± 2.01	0.620
P root-MSF	1.59 ± 2.51	1.96 ± 3.26	0.453	1.99 ± 3.2	1.11 ± 1.63	0.419
MB root-MSF	1.61 ± 2.13	1.23 ± 2.61	0.200	1.37 ± 2.6	1.54 ± 1.58	0.912

* Mann-Whitney, DB = distobuccal, P = palatal, MB = mesiobuccal

Table 4. Comparison of cortical bone thickness and inter-root angles (DB-MB, P-MB, and P-DB) according to molar type, side, and sex.

Variables		P-DB angle	P-MB angle	DB-MB angle	Cortex Thickness
Type of molar	First	49.87 ± 8.92	47.17 ± 7.63	33.02 ± 11.08	0.79 ± 0.23
	Second	40.33 ± 11.86	36.29 ± 12.12	23.42 ± 10.83	0.75 ± 0.21
	P value	0.001>	0.001>	0.001>	0.198
Side	Right	45.49 ± 11.15	42.00 ± 11.74	27.12 ± 12.3	0.76 ± 0.21
	Left	44.1 ± 11.98	40.86 ± 11.46	28.79 ± 11.56	0.77 ± 0.23
	P value*	0.469	0.551	0.396	0.809
Sex	Woman	44.58 ± 12.22	40.6 ± 12.06	26.06 ± 10.58	0.77 ± 0.22
	Man	45.49 ± 9.18	44.12 ± 9.53	34.09 ± 13.98	0.78 ± 0.21
	P value*	0.684	0.116	0.001>	0.788

* Independent t-test, DB = distobuccal, P = palatal, MB = mesiobuccal

4. Discussion

The current investigation observed that the most common relationship between MSF and root apexes apices was type I, where the B and P roots are distant from the MSF, followed by type II, with type IV being the least common. This finding is consistent with previous studies conducted by Kilic et al. (12) and Kwak et al. (11) in Turkish and Korean populations, respectively. However, Robaeian et al.'s study (6) and Haghanifar et al.'s study (1) found that type II (the lower wall of the subsurface sinus that connects the apex of the B and P roots without protrusion apical to the sinus wall) was most common. Differences between results can be attributed to variations in sample size, age range, gender distribution, methodology used, and ethnicity. Various classifications for vertical connection between root apexes apices and MSF have been proposed in dental literature; this study utilized Kwak's classification for analysis.

In line with the current investigation, Robaeian et al., (6) focused on first and second molars of the maxilla while excluding premolars due to anatomical studies indicating closer proximity of MSF to first and second molars (13). However, in this study, we considered the presence of the second molars necessary.

In our study, individuals under 18 years of age were excluded due to the variable growth speed of the maxillary sinus in relation to age. Additionally, teeth with extensive caries extending beyond the pulp chamber, pathological signs of apical periodontitis, and chronic periodontitis were also excluded as they can cause mucosal thickening and other pathological changes in the maxillary sinus teeth with advanced caries extending beyond the pulp chamber, signs of apical periodontitis, or chronic periodontitis were also excluded, as these conditions may lead to mucosal thickening and other pathological alterations in the maxillary sinus. Furthermore, teeth with advanced periodontitis may result in tooth mobility, causing an inaccurate vertical relationship with MSF (14).

In the present study, with a separate investigation of men and women, the mean MB, DB angle in men is significantly higher than that of women, and the results showed that there was no significant difference between the angles in terms of age groups. It was observed in the study of Robaeian et al. (6) that the angle of root divergence was higher in women than in men. Tooth extraction can be challenging if the root divergence angle is high. Before tooth extraction, a higher divergence angle increases the risk of MSF perforation during tooth extraction (1).

Evaluation of the correlation between the divergence angle of maxillary molar roots and their proximity to the MSF showed that in first molars, the mean DB-P angle and MB-P angle are significantly higher compared to second molars. The angle between the B and P roots was also higher than between the B roots for both first and second molars. These findings align with those reported by Haghanifar et al. (1) and Robaeian et al. (6).

After analyzing men and women separately, it was found that men had a significantly higher mean MB-DB angle compared to women. However, there was no significant difference observed between age groups for these angles. It is worth noting that Robaeian et al.'s study (6) found a higher root divergence angle in women than in men. High root divergence angles can pose challenges during tooth extraction as they increase the risk of MSF perforation.

Similar to the present study, the studies conducted by Zhang et al. (5) and Estrela et al. (15) measured the proximity of maxillary molar roots to the MSF and suggested that the shortest distance in the entire population was related to the MB root of the second maxillary molar. However, Kwak et al. (11) and Kilic et al. (12) reported different findings regarding this proximity and suggested the DB root of the second maxillary molar to be the closest one to the MSF. On the other hand, Jung et al.'s study (16) concluded that B roots have the highest protrusion into the sinus. This disparity in the findings can be attributed to the difference in the ethnicity of the studied populations.

In the present study, no significant difference was observed between the MSF and the root apex based on age, while Estrela et al.'s study (15) suggested that this distance increases with age. This difference in results can be due to the fact that in the present study, the number of people over 50 years old was much less than people under 50 years old.

It is interesting to note that in the present research, thickness measurements of the cortex of the MSF were obtained for both first and second molars. These measurements align with those from Estrela et al.'s study (15) in a Brazilian population. The implications of decreased cortical thickness include potential susceptibility to damage as well as increased risk for periapical periodontitis and inflammation spreading to it (17). Furthermore, knowledge about cortical thickness is important for determining orthodontic treatment prognosis and implant stability after maxillary sinus reinforcement (18, 19).

5. Limitations

The retrospective, single-center design may limit the generalizability of the current findings. Furthermore. The relatively small sample size in certain subgroups, such as male participants, may have affected comparative analyses.

6. Conclusion

Based on the present findings, the roots of maxillary molars are usually at a considerable distance from the MSF, with the first molar roots being particularly divergent. This finding underscores the importance of caution when performing extractions on this tooth. Moreover, this study emphasizes the significance of utilizing CBCT to accurately comprehend the anatomy of the posterior maxilla before initiating treatment. This approach serves to minimize potential complications and ensures a more successful treatment outcome.

Ethics

The study protocol was approved by the ethics committee of Mazandaran University of Meical Sciences (code: IR.MAZUMS.REC.1402.17519).

Acknowledgements
This study has been carried out in the Dental College at Mazandaran University, which deserves great appreciation for all academic and financial support.

Using artificial intelligence (AI)
None.

Author contributions
Atefeh Gholampour: Methodology, Conceptualization
Melika Mollaei: Writing – Original draft, Investigation
Fatemeh Ghobadi: Validation
Maedeh Salehi: Supervision
Abolfazl Hosseinnataj: Software, Data Curation
Yeganeh Gholami: Methodology, Supervision

Conflict of interest
The authors declare no conflict of interest.

Funding
None.

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